LABORATORY AND FIELD INVESTIGATIONS
EXAMINING
THE INHIBITION OF
ACID GENERATION FROM PYRITIC MATERIALS

PERD COAL WASTE ROCK PILES

FIELD OBSERVATIONS AND REPORT

Fred Baechler

ADI Nolan Davis

February 25, 1997

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MEMORANDUM

PROJECT NO: 24-4273-001.1

TO: Margarette Kalin and Martin Smith, Boojum Research Ltd.

FROM: Fred Baechler

DATE: November 19, 1996

RE: Investigation of Perd Piles at CBDC's VJCPP

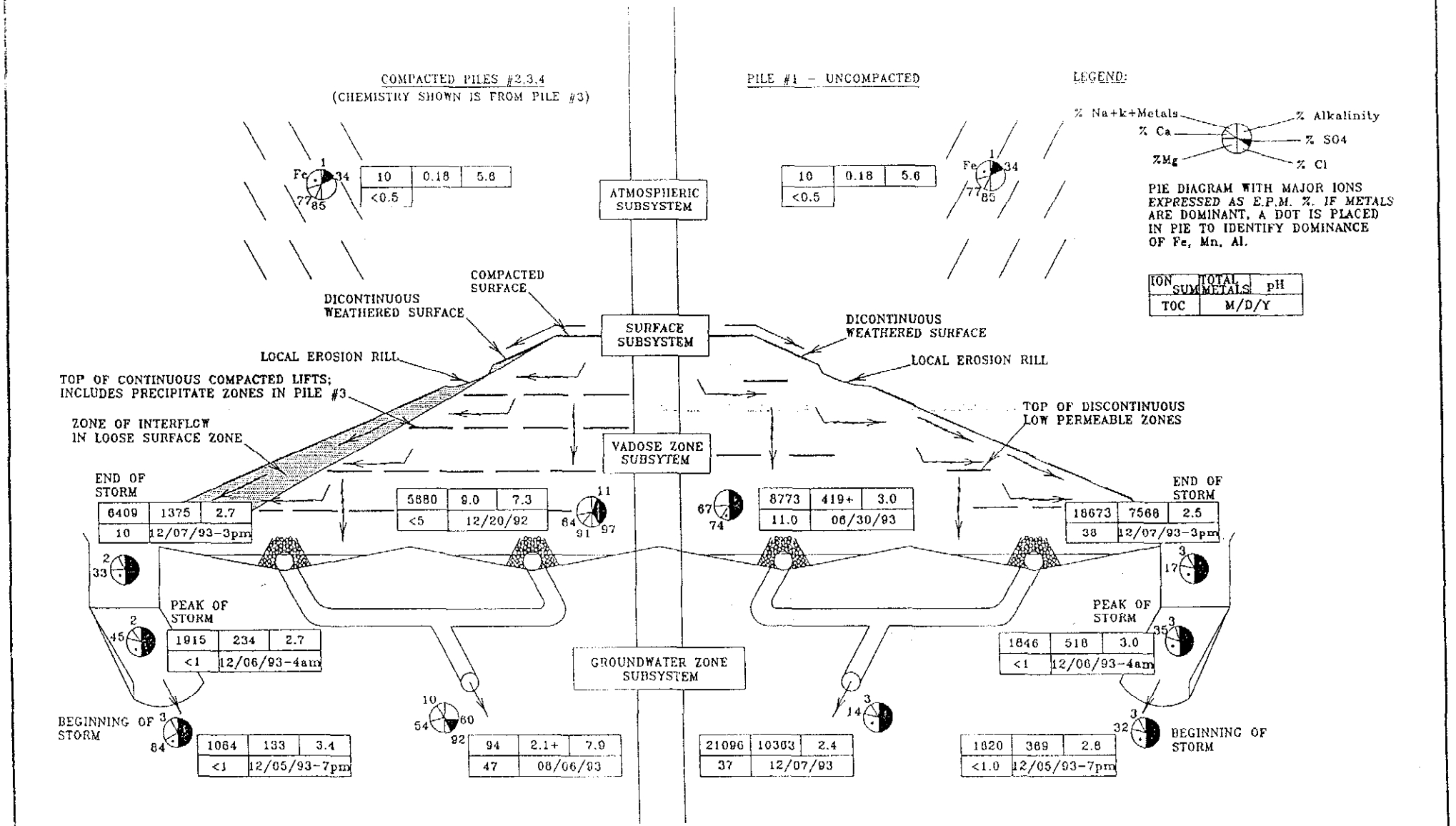
I've summarized my observations from the "autopsy" of PERD Piles 1, 3, 4 and 5 (November 11th-13th, 1996) in the following notes. Pertinent photographs are attached with each description. As is usually the case with acid drainage investigations a lot can be determined through observations of colour. The colour codes used in the descriptions employ the GSA Field rock colour chart on in-situ damp material.

Note Piles 1 and 4 represent the unamended " base" cases against which the limestone and phosphate amended piles can be compared. Pile 4 represents the true base case for comparison, since it was compacted with no amendment; both the limestone (Pile 3) and phosphate (Pile 5) were initially compacted prior to and/or during amendment application. Pile 4 can then be compared to Pile 1 which represents the uncompacted/unamended disposal methodology presently in use in the operational coarse waste pile.

The observations have been compared with what was predicted from the monitoring program. That prediction was presented in the PERD report in the form of a conceptual model of flow and chemistry within the pile. It has been reproduced here in Figure 1.

A list of questions that now need answering and a proposed approach are presented below for deliberation.

- A set of laboratory column experiments should be set up to investigate the attributes of the phosphate versus the limestone hardpan in terms of : strength, permeability to water and oxygen, time to set up, "self- healing" capability, and metal uptake. These characteristics should be reviewed in terms of varying the thickness of the initial amendment layer, its grain size and the thickness of coarse waste required above it to produce sufficient acid generation to initiate the hardpan. During these experiments it would be prudent to determine whether the formation of the hardpan results in an expansion or contraction in volume and whether the process is exothermic. These factors could then, in turn, be related to cost of materials and installation, as well as, the timing of construction in an operational pile.



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Environmental Management
Sydney, Nova Scotia

FIGURE 1
CONCEPTUAL/ANALYTICAL MODEL OF THE HYDROGEOLOGICAL AND GEOCHEMICAL CYCLES WITHIN THE TEST PILES
(REFINEMENT #2, FEB/93)

24-3594-002 1

DRWN BY: N.B. | DATE: MAY/94

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- It will be important to undertake analysis of the samples collected of the coarse waste and hardpan zones during the autopsy, to determine the chemical differentiation occurring in soil geochemistry.

- It would be of interest to determine the chemistry of the yellowish-reddish brown precipitate found in seepage zones and why, in the unsaturated zone, it was just present around the surface of the clasts.

- Two questions have been raised with regard to Pile 4, the compacted or unamended pile, namely:

  1) Why was the compaction alone not sufficient to prohibit weathering from moving downward into the core of the pile?
  2) What process created the precipitate zone some 0.75 m below the surface?

- Given the status of the monitoring probes within the piles and the cost to re-instate them, as well as, the absence of new research monies to install and monitor cover caps over the piles; it is considered prudent to consider undertaking a full autopsy of all five piles. This would include:

  1) Utilizing a drill rig to take continuous split spoon cores at two sites over the top of each pile; the samples to be later analyzed for chemistry.

  2) After the drilling program, a trackhoe would be utilized to excavate out one quarter of each pile to allow for a full 3-D profile to observe, photograph and sample.

  3) If possible, the trackhoe would also be utilized to excavate into certain sections of the operational coarse waste pile to determine the applicability of the PERD Piles to represent scaled up conditions.

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PERD PILE 1 - UNCOMPACTED/UNAMENDED
(similar to existing operational coarse waste pile).

- *Exposure Interval:*
  This pile has been exposed to natural climatic conditions for a total of almost 5.5 years (64 months), since August, 1991.

- *General Appearance:*
  Visual observation of the surface indicates that the pile has maintained its integrity; there are no noticeable slumping or collapse structures. Although only minor (<5 cm deep) rill development occurred along the lower half of the south and east facing slopes, the surface water perimeter drains were filled with coarse waste material eroded off the pile. A lag pavement has been developed over the surface; clasts are 2-5 cm (b axis), encompass a variety of lithologies and do not exhibit any precipitate staining. No surface vegetation or evidence of staining was present over the surface of the pile. When walking over the pile the loose side slopes created a 2-6 cm deep foot print; no indentation was present on the top or the south facing slope over which the drill rig accessed the top of the pile.

- *Instrumentation:*
  The perimeter drains are only partially functional. The underdrains above the till liner appear viable, but no water was available for sampling; the water trap was empty. The header pipe for the under liner collection system was ripped off. The deeper thermocouple is malfunctioning, the status of the oxygen tubes is unknown, and the lysimeters were dry.

- *Test Pit on Top of the Pile:*
  One 0.3 by 0.6 m pit was excavated by hand to a depth of approximately 0.8 m (25 % of the total depth of the pile). The entire depth exhibited a uniform, loose, weathered, "grey", coarse waste material. The "grey" colour can be quantified as light bluish grey (5B7/1) to medium grey (5B5/1). Other than a thin (0.5 cm) friable crust at the surface (probably due to compaction by foot traffic during monitoring) there were no anomalous hardpan or discolored precipitate zones. Throughout the test pit the clasts were noted as exhibiting a "yellow" precipitate mottling their surface; nothing was noted on the matrix, nor, was a halo developed around the clasts. The "yellow" colour comprises two distinct precipitate colours under detailed inspection; namely, moderate yellow (5Y7/6) and very dark red (5R2/6). When viewed from a distance the combination provides the appearance of a pale to dark yellowish orange (10YR8/6 to 10YR6/6).

  The material was damp but no seepage or saturated conditions were encountered. The side walls remained stable; the material removed was returned and infilled the hole with a minimum of tamping by foot. There was no noticeable smell from the pit.

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- *Test Pits on Side Slopes:*
  Three pits were excavated by hand over the side slopes; one mid way down the slope and two at the toe-of-slope.

  At mid-slope a 0.85 m deep hole excavated into the base of a shallow rill revealed a lag pavement over the surface (no staining on the clasts), but no crust. This was underlain by a 0.4 m zone exhibiting the loose, grey, coarse waste noted above with the "yellow" precipitate on the clasts. This zone exhibited a base which generally ran parallel to the surface slope. This was underlain by a "grey" coarse waste with minor precipitate on scattered clasts. This 0.4 m thick zone is expected to represent the Interflow zone noted in the conceptual model, where surface runoff infiltrates into the shallow subsurface along the side slopes then moves quickly down slope to enter the surface perimeter ditches, creating the strong acid component at later stages in the storm hydrographs.

  At the toe-of-slope one pit positioned along the east side wall noted a 5 cm thick "dark red" (dark reddish brown 10R3/4 to very dark red 5R2/6) precipitate zone developed in the underlying till immediately over the plastic liner keyed into the side wall, that underlies the surface perimeter drain. At the northeast corner, where seepage had been noted during rainfall events, a loose 4-8 cm thick heavily "yellow" stained zone was noted in the coarse waste directly over the till liner; a hardpan was not developed.

  The material was damp to wet at both sites, but no seepage was encountered. There was no noticeable smell from either pit.

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PERD PILE 4 - COMPACTED/UNAMENDED
(base compacted case)

- *Exposure Interval*:
  This pile was exposed to natural climatic conditions for almost 5.5 years, the same length of time as Pile 1.

- *General Appearance:*
  Visual observation of the surface indicated that the pile had maintained its integrity; there were no noticeable slumping or collapse structures. Although only minor rill development occurred along the lower half of the south facing slope, the surface water perimeter drains were filled with coarse waste material eroded off the pile. A lag pavement had been developed over the surface similar to Pile 1. No vegetation was growing on the surface of the pile. There was no evidence of surface staining with the exception of light discoloration on the lag pavement over the toe-of-slope in the southwest corner. When walking over the pile, the loose side slopes created a 2-6 cm deep foot print; no indentation was present on the surface or the south facing slope over which the drill rig accessed the top of the pile.

- *Instrumentation:*
  The perimeter drains are only partially functional. The underdrains above the till liner appear viable but only a minor amount of water was available for sampling; the water trap was empty. The header pipe for the under liner collection system was ripped off. The thermocouples were not operative, the status of the oxygen probes is unknown, and the lysimeters were empty.

- *Test Pit on Top of the Pile:*
  One 0.3 x 0.6 m pit was excavated by hand to a depth of approximately 0.9 m(25% of the total depth of the pile). From the surface down to a depth of 0.75 m the coarse waste was no longer compacted and exhibited the same "grey" conditions as found in Pile 1. A zone of heavy "yellow" precipitate was encounter from 0.75 to at least the base of the hole. When excavated the material came up loose (not in cemented fragments). There was no staining zone noticed in the coarse waste above the precipitate zone.

  The material throughout was dry; no saturated conditions were encountered. The side walls remained stable; the material removed was returned and infilled the hole with a minimum of tamping by foot, just as with Pile 1. There was no noticeable smell from the pit.

- *Test Pits on Side Slopes:*
  Two pits were excavated by hand over the side slopes; one mid way down the slope and one at the toe-of-slope, below which the surface was showing evidence of light staining and seepage during rainfall events.

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At mid-slope a 0.85 m deep hole revealed a lag pavement over the surface (no staining on the clasts), but no crust. The excavation revealed a "grey", loose, weathered coarse waste similar to the top 0.75 m described above. The exception was the presence of a 2-5 cm thick highly "yellow" stained zone dipping parallel to slope approximately 5 cm below the surface. It is expected that this provides evidence of the Interflow zone. The toe-of-slope pit exhibited a slight sporadic staining in the top 0.2 m underlain by the regular "grey" coarse waste. At 0.6 m the underlying liner was encountered with a slightly "yellow" stained zone for a couple of cm above it.

Both pits were damp; no saturated conditions or smells were encountered.

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PERD PILE 3 - COMPACTED/LIMESTONE AMENDED:

- *Exposure Interval*:
  This pile was exposed for approximately 5.5 years, the same length of time as Piles 1 and 4.

- *General Appearance:*
  Visual observation of the surface indicates that the pile has maintained its integrity; there are no noticeable slumping or collapse structures. No continuous downslope rill development was present. The surface water perimeter drains are filled with coarse waste material eroded off the pile. A lag pavement has been developed over the surface, although, not to the extent in Piles 1 and 4 (possibly due to the surface limestone layer added during construction). The clasts do not exhibit any precipitate staining.

  The big anomaly with this pile is the sporadic vegetation growth covering the side slopes; none was present over the top. This growth was natural, not due to any man-made seeding activities. There is some lateral continuous growth within the sporadic trend. There was evidence of whitish precipitate locally developed almost as a halo around certain clumps of vegetation.

- *Instrumentation:*
  The perimeter drains are only partially functional. The underdrains above the till liner appear viable but only minor amount of water was available for sampling; the water trap was empty. The thermocouples are no longer functional, the status of the oxygen probes is unknown and the lysimeters were empty.

- *Test Pit on Top of the Pile:*
  One 0.3 x 0.6 m pit was excavated by hand to a depth of approximately 0.7 m(25% of the total depth of the pile). From the surface down to the top of the first limestone layer (approximately 0.1-0.2 m) was loose weathered, "grey" coarse waste, as noted in Piles 1 and 4; although clasts did not exhibit the precipitate layers. Most of the first limestone layer (0.1 m thick) had been converted to a "dark red brown" hardpan, that when broken came to the surface in cemented blocks. This colour was quantified as very dark red (5R2/6) to very dusky red (10R2/2). The pan was difficult to dig through and was dry; some unaltered limestone was sporadically present under the hardpan which had not been altered as yet. There was no evidence of staining in the coarse waste immediately above the hardpan that would indicate a perched water table.

  Beneath the hardpan (from 0.3-0.5 m below surface) was fresh, "black" (dark grey N3 to black N1), compact, dry, coarse waste. The clasts showed no evidence of staining on the surface. It appeared that the hardpan produced a sufficiently low enough permeability to significantly reduce moisture infiltration below it. This was further exemplified when the next limestone layer was encountered . Its 0.1 m thickness was comprised solely of

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fresh greyish orange (10YR7/4) limestone sand, with no evidence of precipitate formation. It in turn was underlain by fresh, coarse waste.

- *Test Pits on Side Slopes:*
One trench was excavated down the east side slope from the top to approximately one third way down the slope, to a point where the second limestone layer was exposed at grade.

The diagram below best summarizes the findings from the trench. The trench was damp; no saturated conditions or smells were encountered. The main points of note include:

1) A loose, "dark red brown", precipitate layer was present parallel to and within 10 cm of the surface, probably resulting from the thin layer of limestone spread over the surface. This was less than 5 cm thick but had not been fully cemented into a hardpan, possibly due to the very thin amount of coarse waste above it for acid generation.

2) The horizontal limestone beds had received precipitate where they intersected the surface. This precipitate however, had not formed a hardpan. It was bright orange (no code available) in colour. However, the development of a hardpan did not commence for 10-20 cm back from the surface. Even then the hardpan was very thin. Excavation into the bank indicated that a hardpan of greater than 1 cm thickness which was underlain by fresh coarse waste did not occur until approximately 0.7 - 1.8 m in from the surface slope. It was at this point that it appeared sufficient overlying coarse waste was present (approximately 0.4-0.6 m thick) to create the acid drainage required to develop the pan.

3) The second limestone hardpan exhibited a thin (1-4 cm) zone of wet coarse waste with "yellow" precipitate immediately above the hardpan. This would denote perched water table conditions, with seepage directed laterally out to the interflow zone and then to the surface drains; thereby, directing flow away from the underdrains. This would explain the absence of underdrain flow for such a long time in this pile and its initial high pH. It could also explain the whitish precipitate halos around some of the vegetation; this, being a result of the evaporation of slow moving groundwater seepage perched over the hardpans as it discharged at surface. Such drainage would probably be of an elevated pH and would aid in the establishment of the vegetation.

4) The interflow zone on this pile is therefore disrupted by perched water tables associated with the limestone hardpan. However, these lateral

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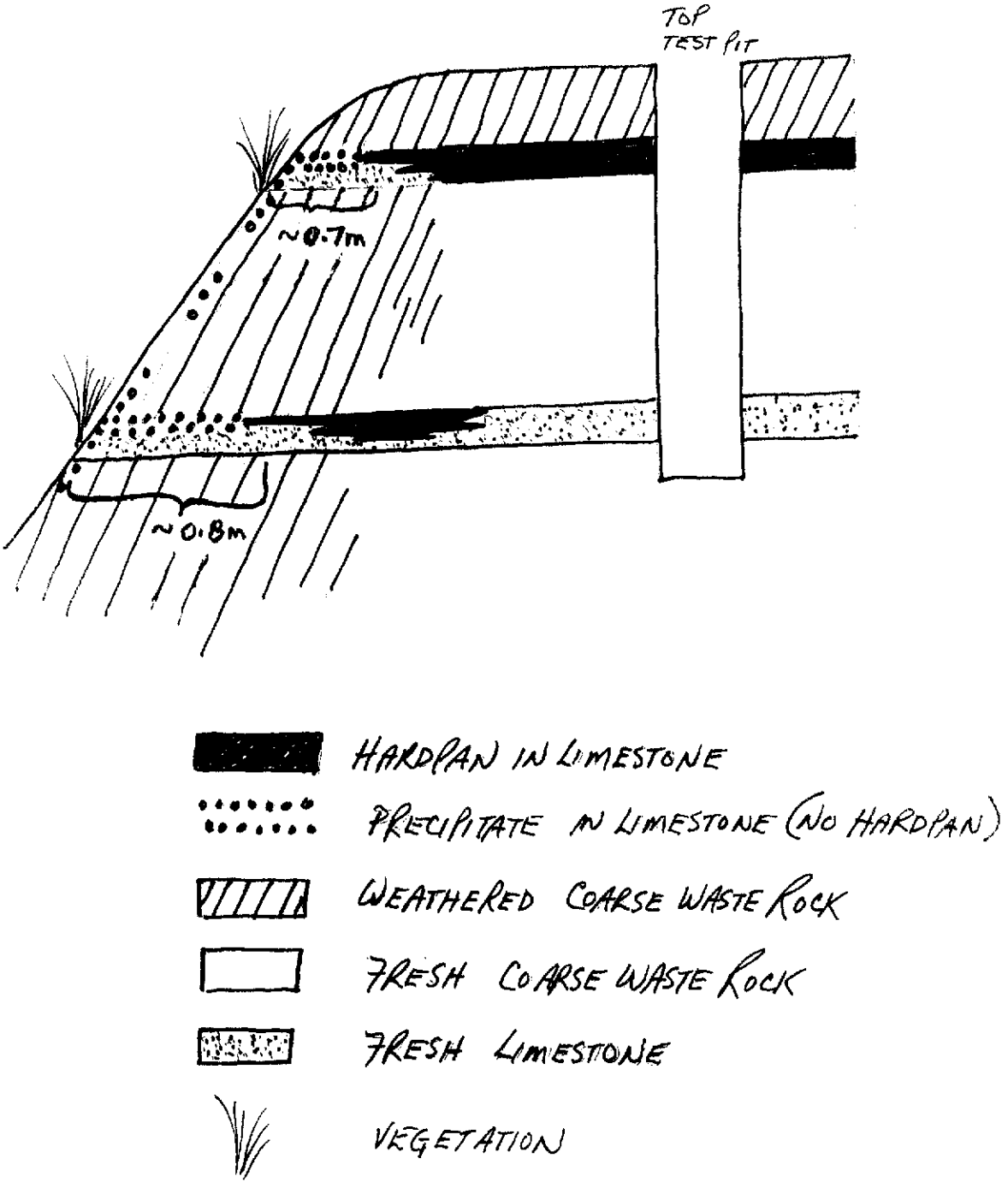
hardpan layers will not extend deep into the core of the pile as noted from the surface test pit.



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PERD PILE 5 - COMPACTED/PHOSPHATE AMENDED:

- *Exposure Interval*
  This pile was exposed for only four (4) years or approximately 80% of the exposure time for the other Piles.

- *General Appearance:*
  Visual observation of the surface indicated that the pile had maintained its integrity; there were no noticeable slumping or collapse structures. The side slope benches and surface depression over the top are still functional. One major, continuous, downslope gully was present over the southeast corner, which drained the depression in the top of the pile. The surface water perimeter drains are filled with coarse waste material eroded off the pile. A lag pavement has been developed over the surface of the side slopes. There has been some damage done by site operations, specifically, the surface water outflow has been eradicated by a new road. No vegetation was present on the surface of the pile; no staining was in evidence.

- *Instrumentation:*
  The perimeter drains are only partially functional. The underdrain above the till liner had no water trap and no water was available for sampling. One of the thermocouples appears inoperative; the status of the oxygen ports is unknown. The pan lysimeters appeared functional but dry.

- *Test Pit on Top of the Pile:*
  Two 0.3 x 0.6 m pits were excavated by hand in the surface depression to a depth of 0.3 m (10% of the total depth of the pile). The surface lag pavement was obscured by deposition of fines over the center of the depression. Both pits exhibited similar conditions. From the surface, down to the top of the phosphate layer, (approximately 0.2 m) was loose, weathered, "grey" coarse waste as noted in Piles 1 and 4. There was evidence of slight "yellow" mottling immediately above the phosphate hardpan layer indicating possible ephemeral perched conditions. Most of the phosphate layer had been turned into a very strong, "orange brown" hardpan, approximately 2-3 cm thick; which came to the surface as cemented blocks. This colour ranged from dark yellowish orange (10YR6/6) to moderate yellowish brown (10YR5/4). The natural phosphate sand was a light brown (5YR5/6). The pan was difficult to dig through and was dry; some phosphate sand was sporadically present under the hardpan which had not been altered as yet. The hardpan was underlain by relatively fresh, black, compacted, coarse, waste rock.

  Two similar sized pits were excavated on the top of the pile but near the edge or "shoulder". The pit positioned on the western shoulder indicated similar conditions to that described above, with the exception of two separate but continuous (for at least 0.2-0.3 m) cracks paralleling the edge of the pile. The cracks were 2-5 cm in width and extended to the base of the phosphate layer, which had been entirely turned to hardpan.

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This suggests that after hardening tension cracks formed from the weight of the down slope portion of the hardpan. Although the depth of phosphate allowed the crack to self-heal, the layer eventually ran out and the crack disected the entire hardpan allowing water and air to permeate into the core of the pile. However, the pit excavated into the shoulder at the southeast corner where the major rill was present, revealed no cracks in the hardpan.

Test Pits on Side Slopes:

Three trenches were excavated down the side slopes, two on the side slopes and one at the southeast corner which followed the gully downslope. All trenches indicated that the phosphate layer was not constructed over the lower third of the slope. It is thought that this was due to construction problems in placing the material over the steeper lower slopes, required to squeeze Pile 5 into the only space left available. Since the hardpan would not have been properly seated at the toe of the slope, the weight of the hardpan over the slope could have created the tension cracks noted.

The hardpan did control the depth of gullying by creating an essentially non-erodible base. In this area the surface of the hardpan was smooth; there were no cracks noticeable all the way down the slope.

The trench excavated below where the tension cracks appeared, exhibited a totally different situation. It is of note, that this was in line with where the lysimeter lines came to surface. Immediately below the edge of the pile the surface of the hardpan was very contorted and irregular. In addition, a number of horizontal microcracks were present. The yellowish-reddish brown staining was noticeable as thin lenses parallel to slope within the upper weathered coarse waste. In one instance it was 0.3 m thick directly over the phosphate layer; thought to be possible pooling of interflow waters within depressions in the hardpan.

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AUTOPSY OF PERD PILE 1
UNCOMPACTED - NO AMENDMENT

November 11th-13th, 1996

Plate 2: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Overview, south facing slope.

Plate 3: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Lag pavement over surface.

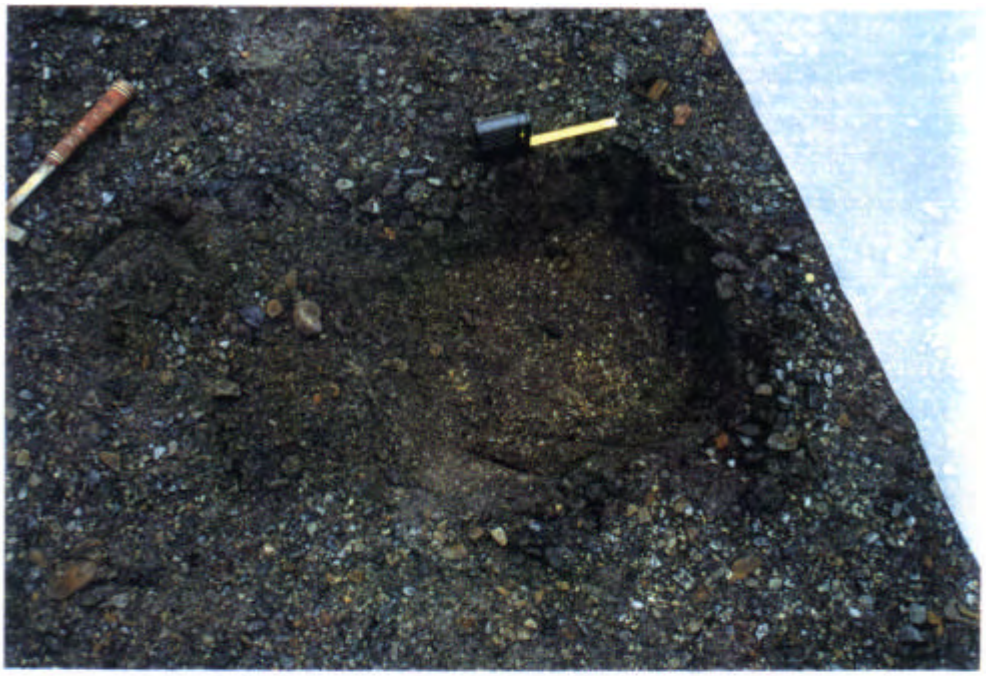

Plate 4: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. First pit surface layers.

Plate 5: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Surface crust.

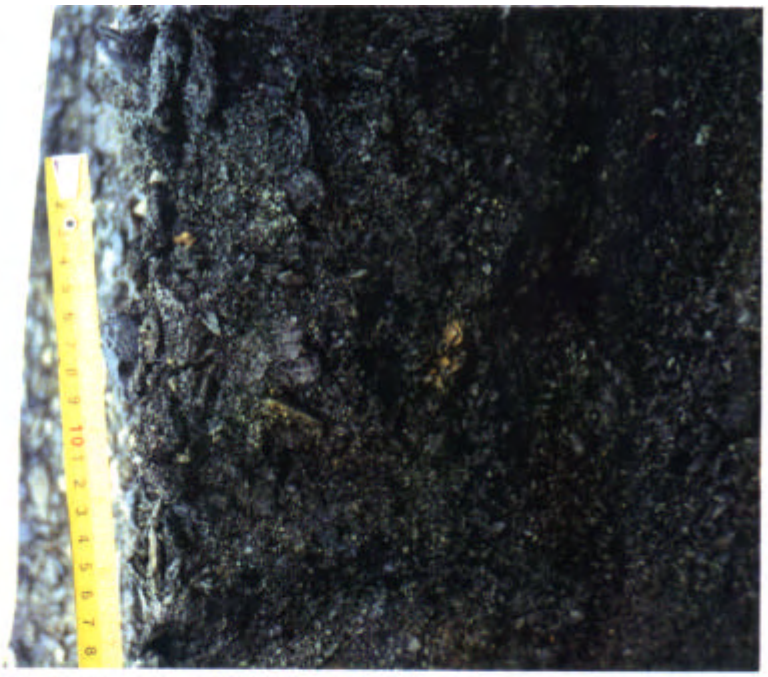

Plate 6: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. First pit over top.

Plate 7: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. First pit over top.

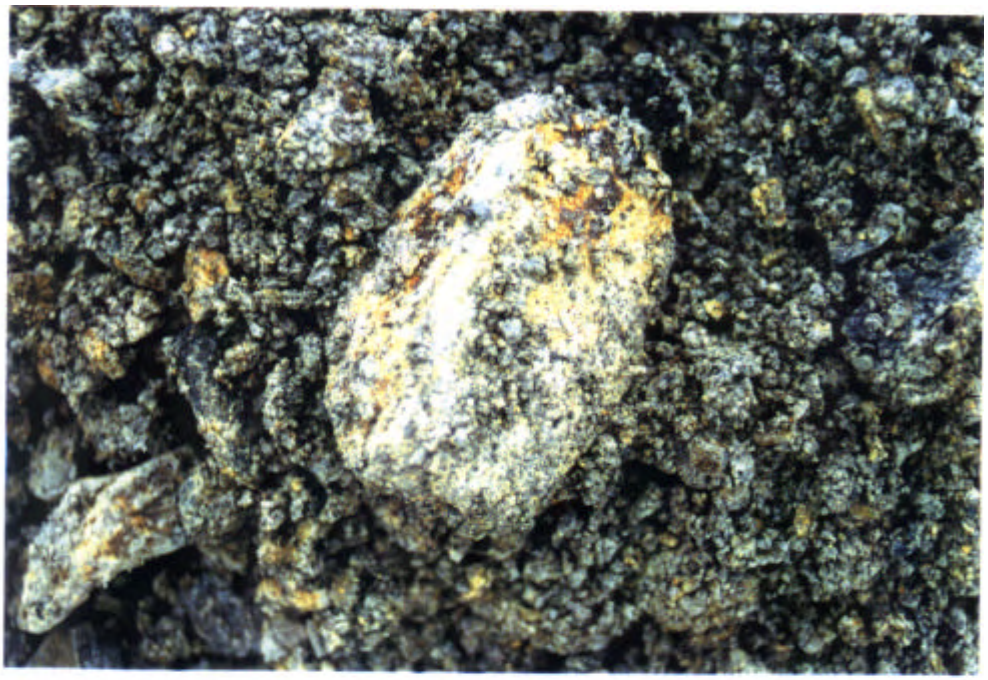

Plate 8: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Staining on clasts out of pit 1.

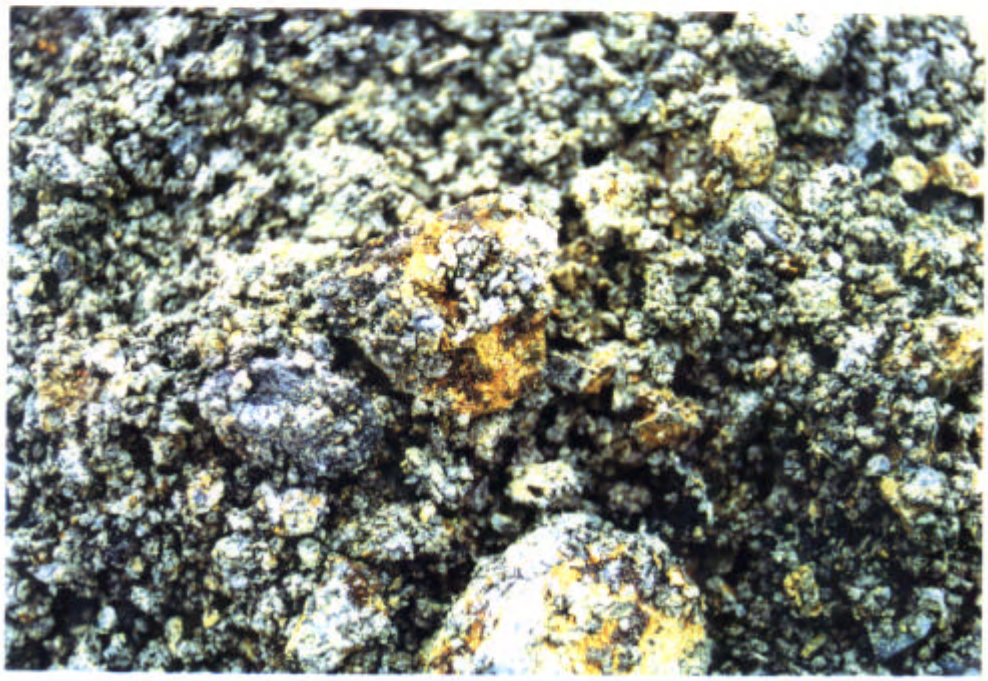

Plate 9: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Staining on clasts out of pit 1.

Plate 10: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Pit 1 materials after completion of pit 1 excavation.

Plate 11: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. E facing side slope where side pits dug.

Plate 12: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996
Mid slope pit.

Plate 13: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996
Close up of mid slope pit.

Plate 14: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Mid slope pit.

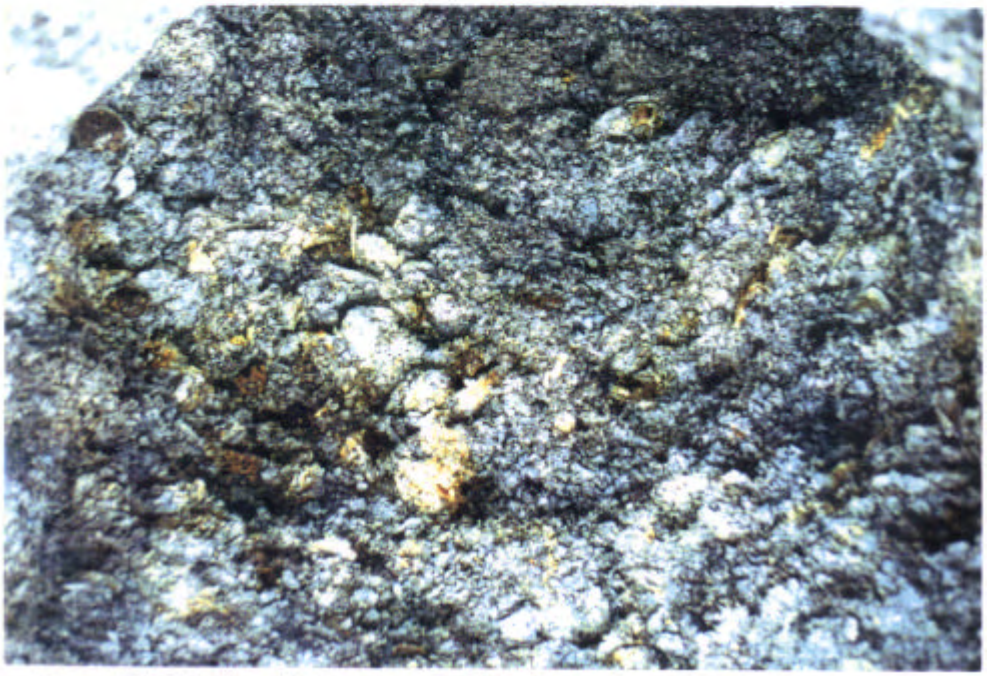

Plate 15: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Mid slope pit. Close-up of staining near surface.

Plate 16: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Toe of slope pit.

Plate 17: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Toe of slope pit close-up. Note staining over vapour barrier.

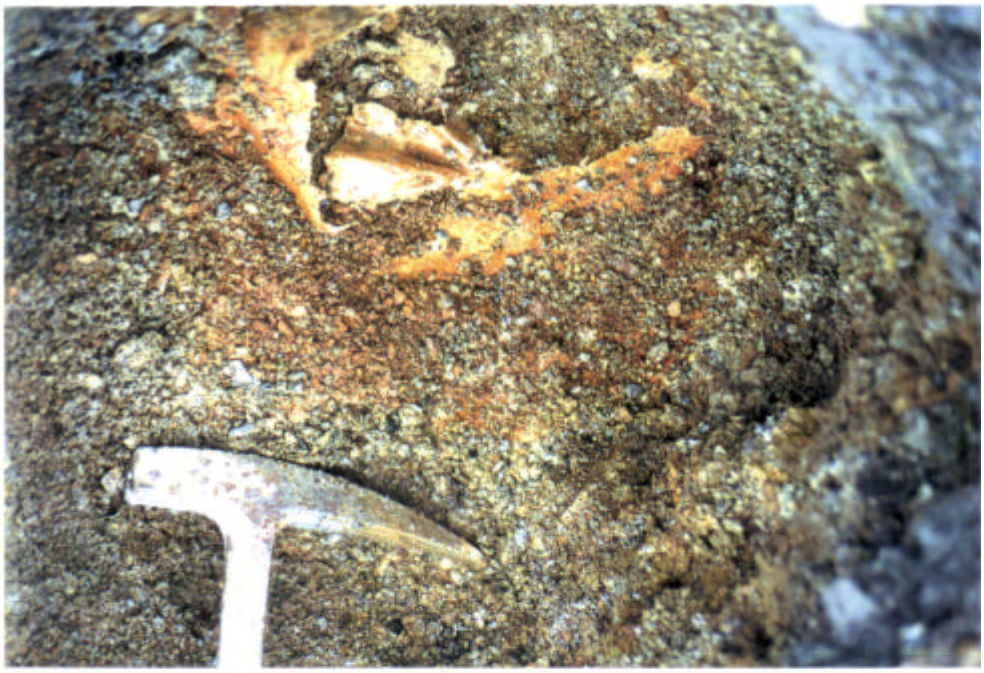

Plate 18: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Toe of slope pit. Close-up of staining over vapour barrier.

Plate 19: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Toe of slope pit at N-E corner just above surface staining.

Plate 20: PERD Pile 1, Uncompacted, No Amendment, November 11-13, 1996. Toe of slope pit at N-E corner. Close-up of staining.

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AUTOPSY OF PERD PILE 3
COMPACTED - LIMESTONE AMENDED

November 11-13th, 1996

Plate 21: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Overview of S facing slope.

Plate 22: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Overview of W facing slope.

Plate 23: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Overview of N facing slope.

Plate 24: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Overview of N-W corner.

Plate 25: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Pit at top of pile.

Plate 26: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Close-up of pit at top of pile, down to just below second limestone layer.

Plate 27: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Pit,top of pile. Weathered coarse coal waste above first limestone layer.

Plate 28: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Pit,top of pile. First limestone layer hardpan.

Plate 29: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Pit,top of pile. Fresh coarse coal waste below limestone hardpan.

Plate 30: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Completed excavation of top pit.

Plate 31: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. trench excavated down E facing slope.

Plate 32: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. trench excavated down E facing slope, side view.

Plate 33: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Close-up of trench excavated down E facing slope, surface down to second limestone layer.

Plate 34: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Close-up of E facing slope trench where first limestone band meets surface of slope.

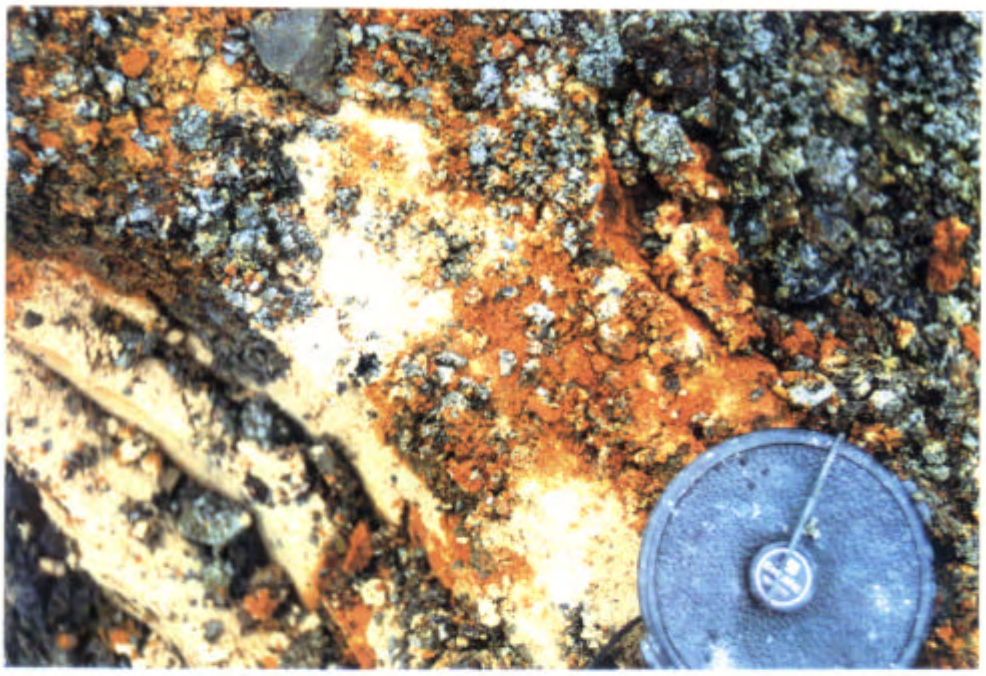

Plate 35: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Close-up of E facing slope trench where first limestone band meets surface of slope.

Plate 36: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Close-up of E facing slope trench where first limestone band meets surface of slope.

Plate 37: PERD Pile 3, Compacted, Limestone Amended, November 11-13, 1996. Close-up of E facing slope trench where good harpan starts on second limestone layer back in slope.

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AUTOPSY OF PERD PILE 4
COMPACTED - NO AMMENDMENT

November 11-13th, 1996

Plate 38: PERD Pile 4, Compacted, No Amendment, November 11-13, 1996. S-W corner. Note staining in forground.

Plate 39: PERD Pile 4, Compacted, No Amendment, November 11-13, 1996. Pit excavated on top.

Plate 40: PERD Pile 4, Compacted, No Amendment, November 11-13, 1996. Weathered coarse coal waste in top pit.

Plate 41: PERD Pile 4, Compacted, No Amendment, November 11-13, 1996. Mid-slope and toe of slope pits on SW corner.

Plate 42: PERD Pile 4, Compacted, No Amendment, November 11-13, 1996. Toe of slope pit.

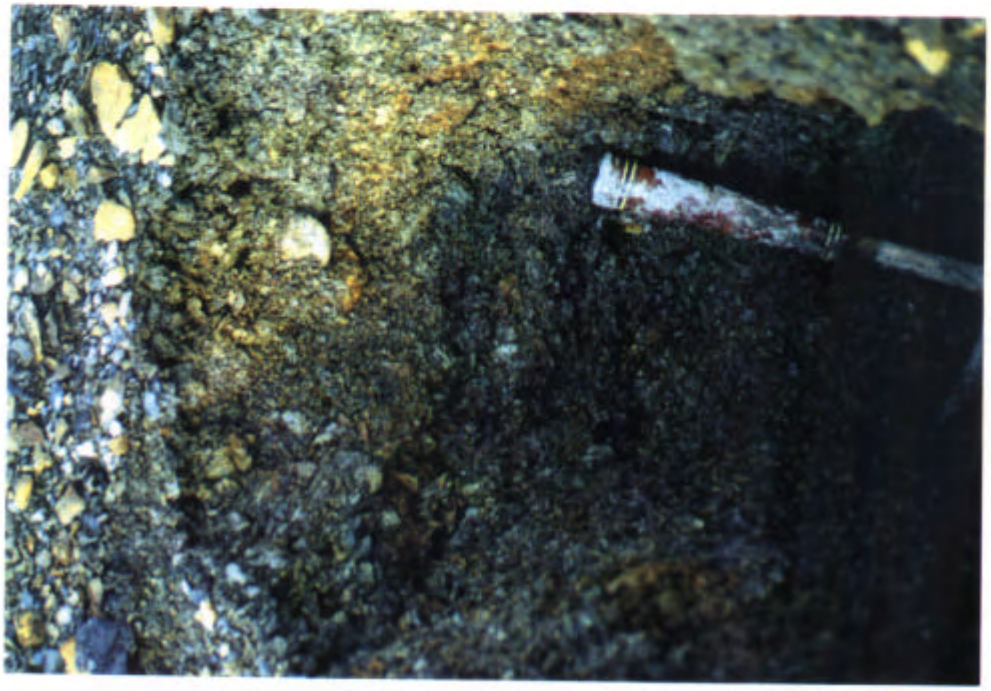

Plate 43: PERD Pile 4, Compacted, No Amendment, November 11-13, 1996. Toe of slope pit.

Plate 44: PERD Pile 4, Compacted, No Amendment, November 11-13, 1996. Mid-slope pit.

Plate 45: PERD Pile 4, Compacted, No Amendment, November 11-13, 1996. Mid-slope pit.

Plate 46: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Overview of N-facing slope.

Plate 47: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Overview of W-facing slope.

Plate 48: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Rill created by erosion at S-E corner.

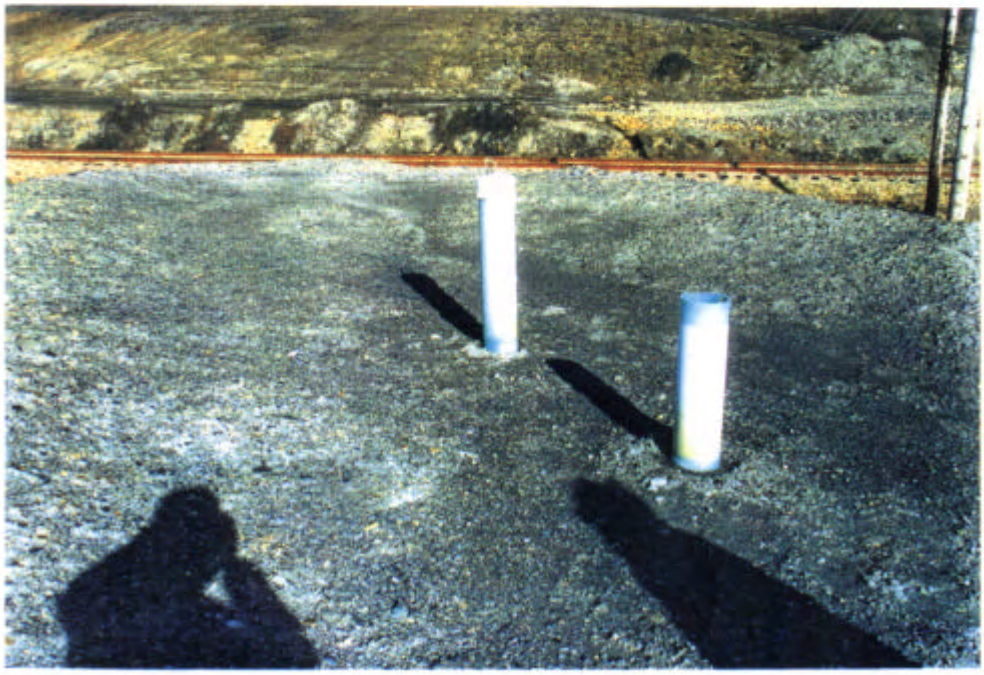

Plate 49: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Depression on top of pile.

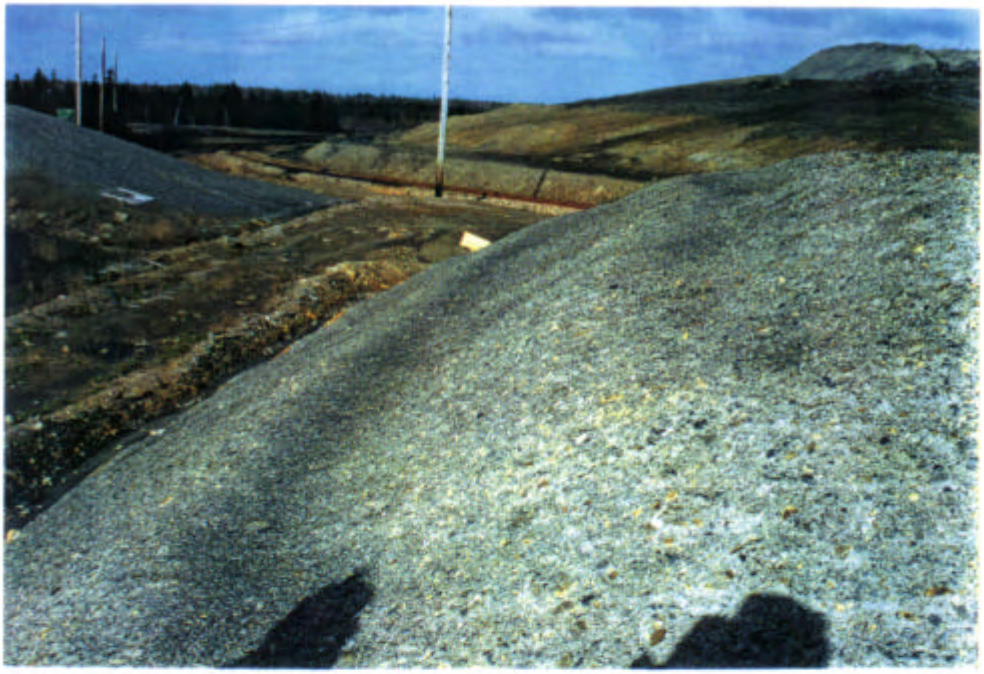

Plate 50: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Depressions built into side to collect water.

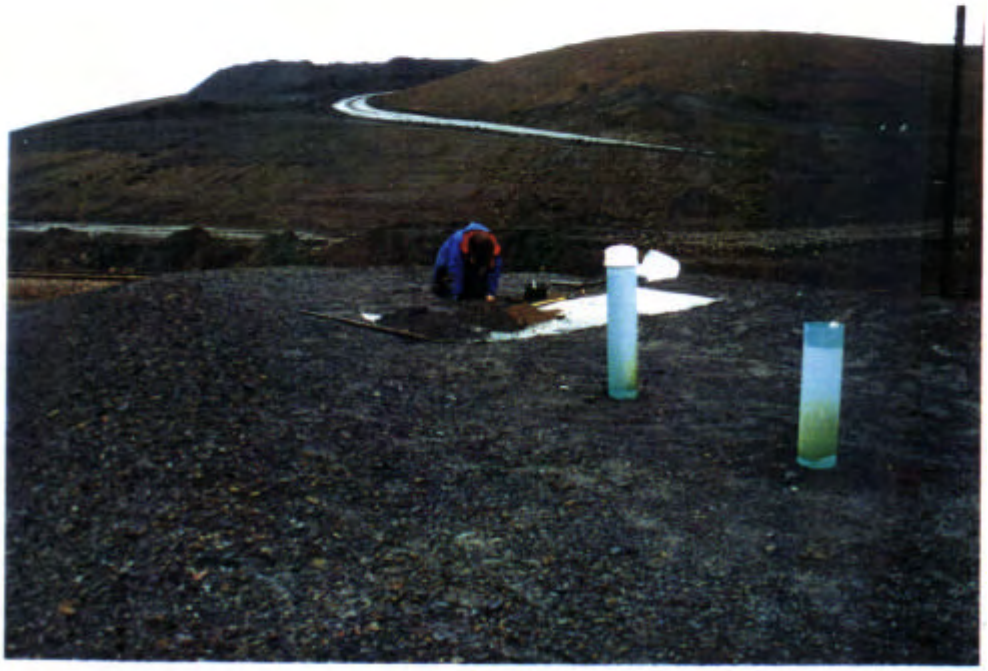

Plate 51: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. First pit on top.

Plate 52: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996
First pit on top, upper coal waste and phosphate rock layer materials.

Plate 53: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996.
First pit on top. Phosphate hardpan layer.

Plate 54: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. First pit on top. Phosphate hardpan layer.

Plate 55: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. First pit on top. Phosphate hardpan layer close-up.

Plate 56: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Completed excavation of first pit on top.

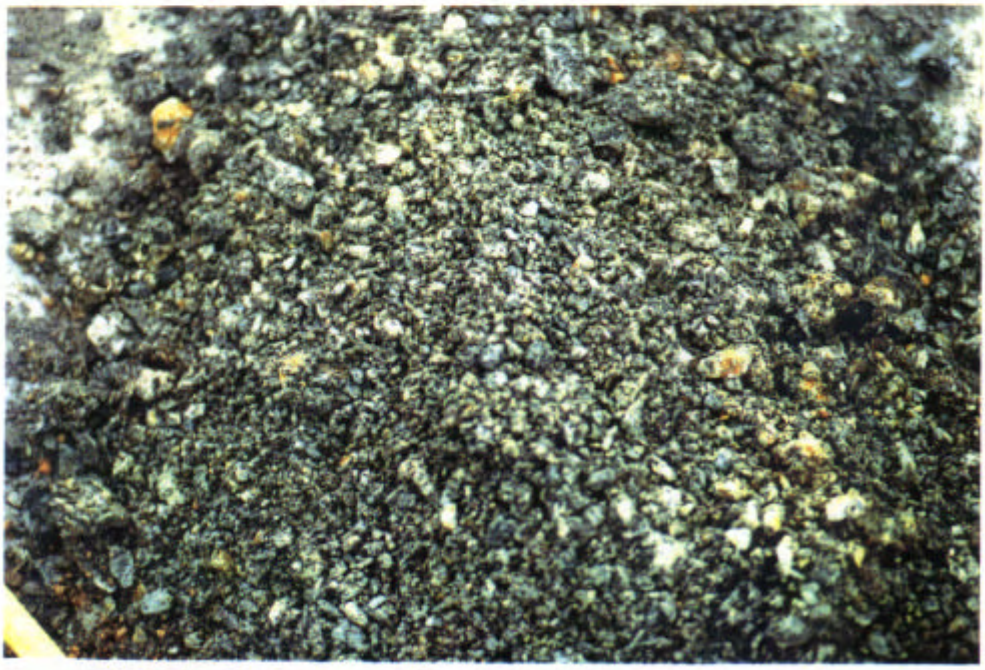

Plate 57: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Weathered coarse coal waste from top layer.

Plate 58: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Unaltered coarse coal waste from below hardpan layer.

Plate 59: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Second pit on top shoulder of W facing slope.

Plate 60: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Exposed hardpan layer in second pit on top shoulder.

Plate 61: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Exposed hardpan layer with cracks in extended second pit on top shoulder.

Plate 62: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Top shoulder second pit overview.

Plate 63: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Exposed hardpan layer with cracks in extended second pit on top shoulder.

Plate 64: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Overview of pile.

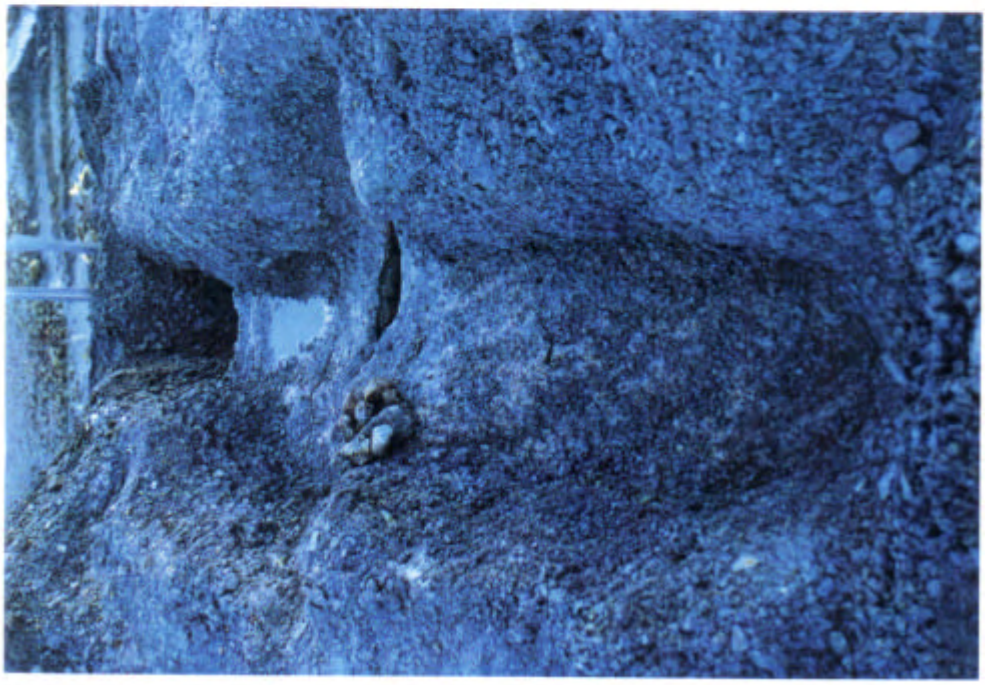

Plate 65: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. West side trench exposing hardpan extending from top surface down side.

Plate 66: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. West side trench exposing hardpan extending from top surface down side.

Plate 67: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. West side trench exposing hardpan extending from top surface down side.

Plate 68: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. West side trench extending from top surface down side.

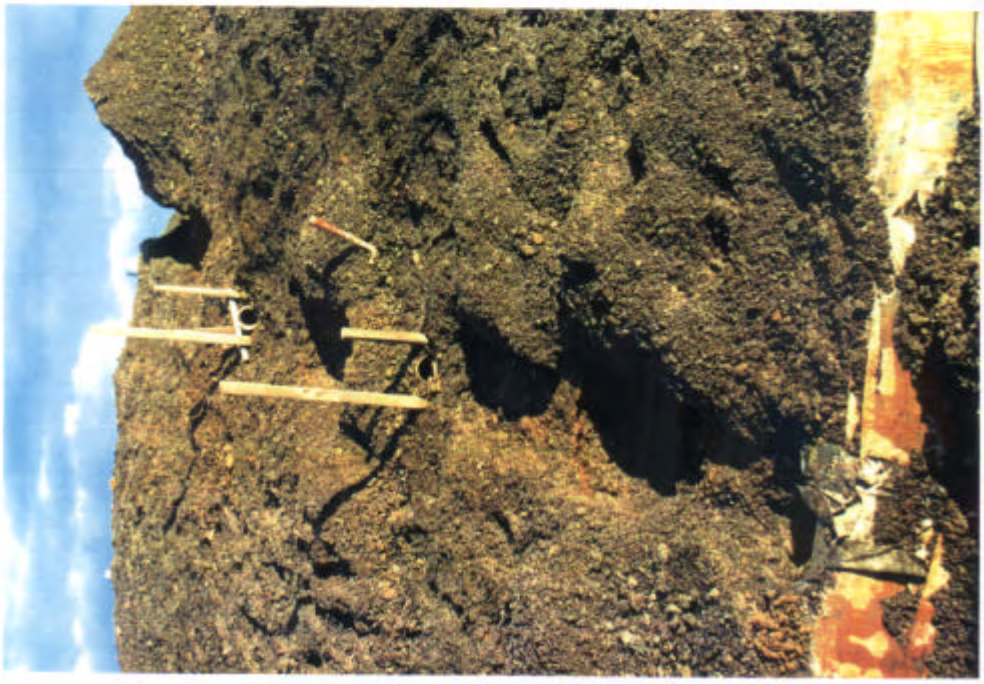

Plate 69: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Completed west side trench extending from top surface down side.

Plate 70: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Base of west side trench showing end of phosphate hardpan layer.

Plate 71: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Base of west side of showing weathered coal waste beneath liner.

Plate 72: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Close-up of base of west side of showing weathered coal waste beneath liner.

Plate 73: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Third pit excavated under natural rill on east side on pile.

Plate 74: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Third pit excavated under natural rill on east side on pile. Viewed from slope bottom.

Plate 75: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Third pit excavated under natural rill on east side on pile. Note absence of cracks.

Plate 76: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Third trench excavated under natural rill on east side on pile.

Plate 77: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. overview of third trench excavated under natural rill on east side on pile.

Plate 78: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Overview of east side of pile.

Plate 79: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Excavation on south side of pile exposing limit of phosphate hardpan.

Plate 80: PERD Pile 5, Compacted, Phosphate Amended, November 11-13, 1996. Close-up of excavation on south side of pile exposing limit of phosphate hardpan.